

# CW 3GeV Linac Error Simulations at 10 mA/ 650 Hz LE+HE 24-Sept-2010

40 parameters scanned / TRACKv39\_15JUNE2010 (TRACK  
version benchmarked with ASTRA)

Jean-Paul Carneiro

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# ALIGN/ALGN2 Parameter TRACKv39

n **ALIGN** name  $\delta_{xy}$   $\delta_z$   $\phi_z$   $\delta\phi_{dyn.}$   $\delta F_{dyn.}$   $\delta\phi_{static}$   $\delta F_{static}$

n **ALGN2** name  $\delta_x$   $\delta_y$   $\delta_z$   $\phi_x$   $\phi_y$   $\phi_z$   $\delta\phi_{dyn.}$   $\delta F_{dyn.}$   $\delta\phi_{static}$   $\delta F_{static}$

- ▶  $\delta_{xy}[cm]$  From the max allowed displacement of element ends, the maximum allowed rotation is calculated. Then the random errors are generated for both displacement and rotation. The generated errors are accepted only if the final displacements of the element ends is within the tolerance (max allowed displacement) specified as input. Uniform distribution.
- ▶  $\delta_x[cm]$  Displacement parallel to the x-axis. Uniform distribution.
- ▶  $\phi_x[mrad]$  Rotation of the element with respect to the center of the element. Uniform distribution
- ▶  $\delta\phi_{dyn.}[deg]$  : Amplitude of the dynamic phase error of the device. Gaussian distribution truncated at 3 sigma.
- ▶  $\delta F_{dyn.}[\%]$  : Amplitude of the dynamic field error of the device. Gaussian distribution truncated at 3 sigma.
- ▶  $\delta\phi_{static}[deg]$  : Amplitude of the static phase error of the device. Uniform distribution.
- ▶  $\delta F_{static}[\%]$  : Amplitude of the static field error of the device.

# Error Simulation (16000 runs)

- ▶ From RFQ exit to end of the CW 3 GeV linac ( $\sim 374$  meters)
- ▶ 40 errors simulated with TRACKv39
- ▶ Each error simulated with 400 seeds with 3D SC (10 mA) and 50k per seed
- ▶  $40 \times 400 = 16000$  runs with TRACKv39 on FermiGrid

# Parameters 01-20

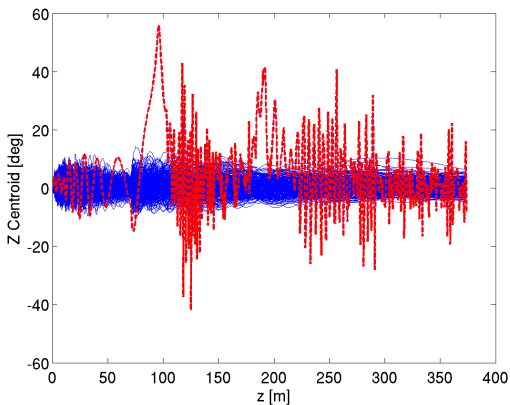
- ▶ 01/ Solenoids  $\delta_x = 150 \mu\text{m}$
- ▶ 02/ Solenoids  $\delta_x = 300 \mu\text{m}$
- ▶ 03/ Solenoids  $\delta_x = 500 \mu\text{m}$
- ▶ 04/ Solenoids  $\delta_x = 750 \mu\text{m}$
- ▶ 05/ Solenoids  $\delta_x = 1000 \mu\text{m}$
- ▶ 06/ Solenoids  $\phi_x = 1 \text{ mrad}$
- ▶ 07/ Solenoids  $\phi_x = 2 \text{ mrad}$
- ▶ 08/ Solenoids  $\phi_x = 3 \text{ mrad}$
- ▶ 09/ Solenoids  $\phi_x = 4 \text{ mrad}$
- ▶ 10/ Solenoids  $\phi_x = 5 \text{ mrad}$
- ▶ 11/ Solenoids  $\delta_{xy} = 150 \mu\text{m}$
- ▶ 12/ Solenoids  $\delta_{xy} = 300 \mu\text{m}$
- ▶ 13/ Solenoids  $\delta_{xy} = 500 \mu\text{m}$
- ▶ 14/ Solenoids  $\delta_{xy} = 750 \mu\text{m}$
- ▶ 15/ Solenoids  $\delta_{xy} = 1000 \mu\text{m}$
- ▶ 16/ Quads  $\delta_x = 150 \mu\text{m}$
- ▶ 17/ Quads  $\delta_x = 300 \mu\text{m}$
- ▶ 18/ Quads  $\delta_x = 500 \mu\text{m}$
- ▶ 19/ Quads  $\delta_x = 750 \mu\text{m}$
- ▶ 20/ Quads  $\delta_x = 1000 \mu\text{m}$

# Parameters 21-40

- ▶ 21/ Quads  $\delta_{xy} = 150 \mu\text{m}$
- ▶ 22/ Quads  $\delta_{xy} = 300 \mu\text{m}$
- ▶ 23/ Quads  $\delta_{xy} = 500 \mu\text{m}$
- ▶ 24/ Quads  $\delta_{xy} = 750 \mu\text{m}$
- ▶ 25/ Quads  $\delta_{xy} = 1000 \mu\text{m}$
- ▶ 26/ Cav. Phase  $\delta F_{dyn} = 0.5 \%$
- ▶ 27/ Cav. Phase  $\delta F_{dyn} = 1.0 \%$
- ▶ 28/ Cav. Phase  $\delta F_{dyn} = 1.5 \%$
- ▶ 29/ Cav. Phase  $\delta F_{dyn} = 2.0 \%$
- ▶ 30/ Cav. Phase  $\delta F_{dyn} = 2.5 \%$
- ▶ 31/ Cav. Field  $\delta\phi_{dyn.} = 0.5^\circ$
- ▶ 32/ Cav. Field  $\delta\phi_{dyn.} = 1.0^\circ$
- ▶ 33/ Cav. Field  $\delta\phi_{dyn.} = 1.5^\circ$
- ▶ 34/ Cav. Field  $\delta\phi_{dyn.} = 2.0^\circ$
- ▶ 35/ Cav. Field  $\delta\phi_{dyn.} = 2.5^\circ$
- ▶ 36/  $\delta\phi_{dyn.} = 0.5^\circ$  &  $\delta F_{dyn} = 0.5 \%$
- ▶ 37/  $\delta\phi_{dyn.} = 1.0^\circ$  &  $\delta F_{dyn} = 1.0 \%$
- ▶ 38/  $\delta\phi_{dyn.} = 1.5^\circ$  &  $\delta F_{dyn} = 1.5 \%$
- ▶ 39/  $\delta\phi_{dyn.} = 2.0^\circ$  &  $\delta F_{dyn} = 2.0 \%$
- ▶ 40/  $\delta\phi_{dyn.} = 2.5^\circ$  &  $\delta F_{dyn} = 2.5 \%$

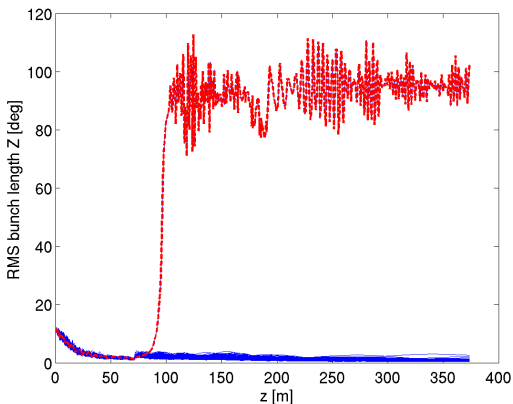
Seed 235 = worst seed for 1% +1 deg. RF Dyn. +  $\sim 10$  seeds more

Figure: Centroid Z [deg] / Seed 235



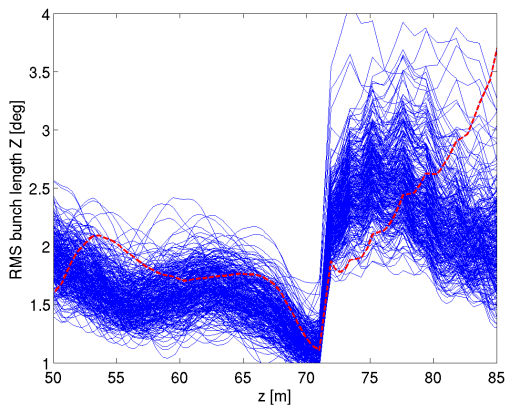
Seed 235 = worst seed for 1% +1 deg. RF Dyn. +  $\sim 10$  seeds more

Figure: RMS Z [deg] / Seed 235



Seed 235 = worst seed for 1% +1 deg. RF Dyn. +  $\sim 10$  seeds more

Figure: RMS Z Zoom [deg] / Seed 235





# (002) Solenoids $\delta_x = 300 \mu\text{m}$

Figure: RMS Emittance X

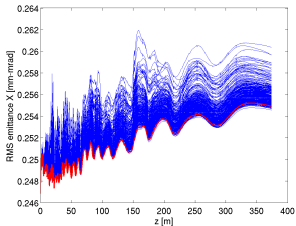


Figure: Centroid X

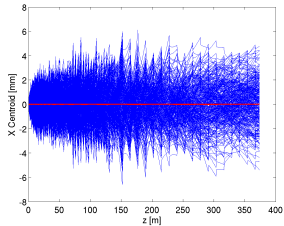


Figure: RMS Emittance Z

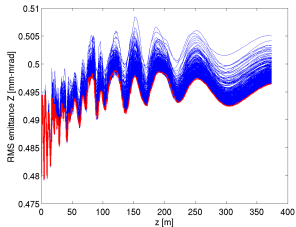
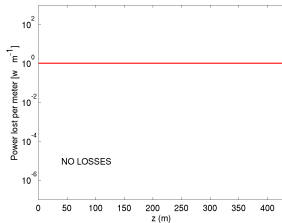


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (003) Solenoids $\delta_x = 500 \mu\text{m}$

Figure: RMS Emittance X

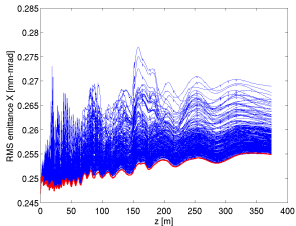


Figure: Centroid X

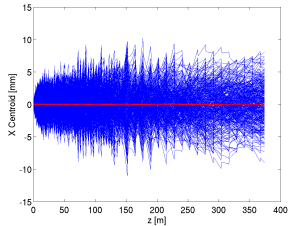


Figure: RMS Emittance Z

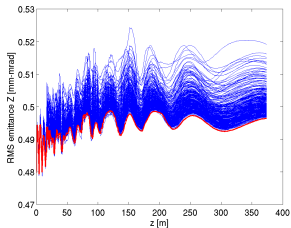
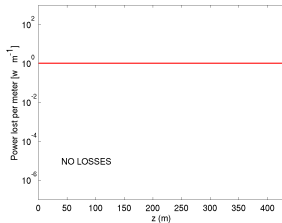


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (004) Solenoids $\delta_x = 750 \mu\text{m}$

Figure: RMS Emittance X

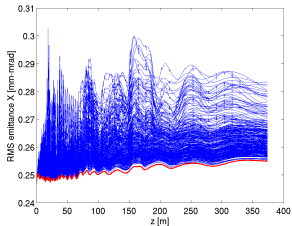


Figure: Centroid X

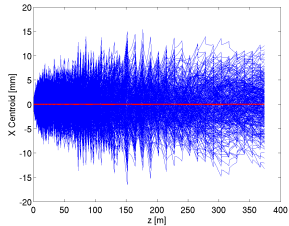


Figure: RMS Emittance Z

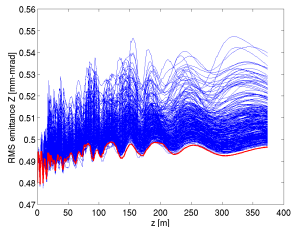
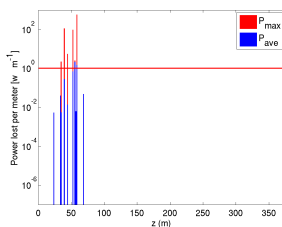


Figure: Losses  $[\text{W}\cdot\text{m}^{-1}]$



# (005) Solenoids $\delta_x = 1000 \mu\text{m}$

Figure: RMS Emittance X

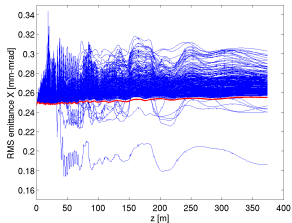


Figure: Centroid X

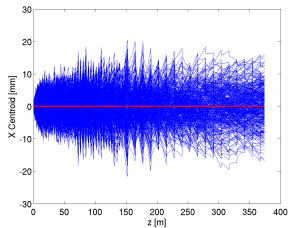


Figure: RMS Emittance Z

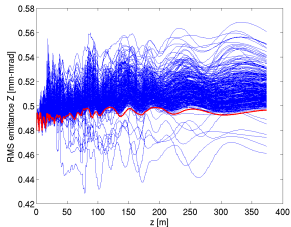
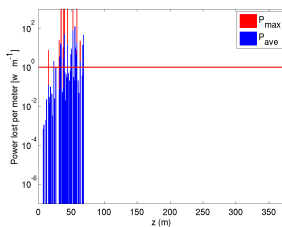


Figure: Losses  $[\text{W}\cdot\text{m}^{-1}]$



# (006) Solenoids $\phi_x = 1$ mrad

Figure: RMS Emittance X

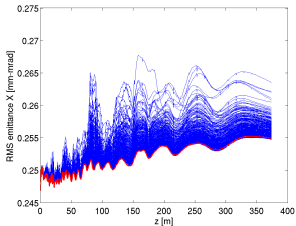


Figure: Centroid X

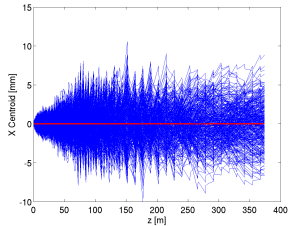


Figure: RMS Emittance Z

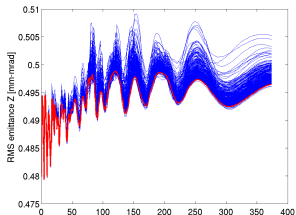
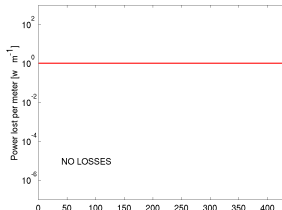


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (007) Solenoids $\phi_x = 2$ mrad

Figure: RMS Emittance X

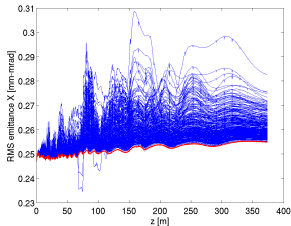


Figure: Centroid X

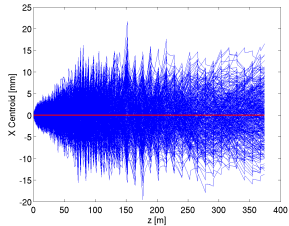


Figure: RMS Emittance z

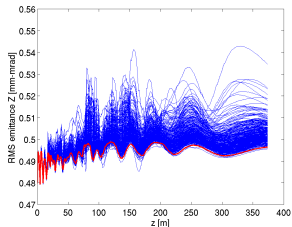
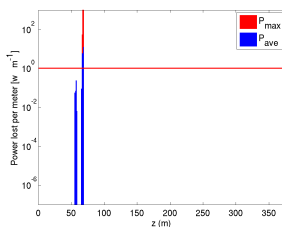


Figure: Losses  $[\text{W} \cdot \text{m}^{-1}]$



# (008) Solenoids $\phi_x = 3$ mrad

Figure: RMS Emittance X

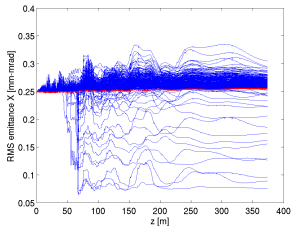


Figure: Centroid X

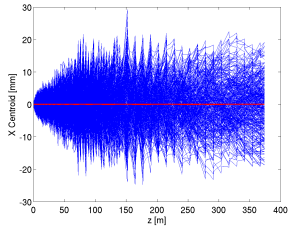


Figure: RMS Emittance Z

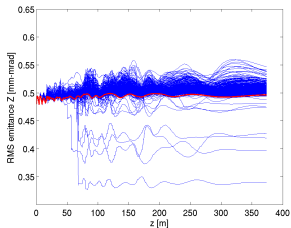
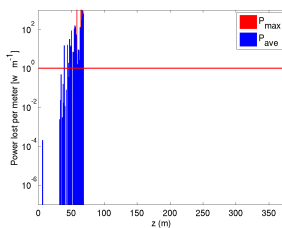


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



# (009) Solenoids $\phi_x = 4$ mrad

Figure: RMS Emittance X

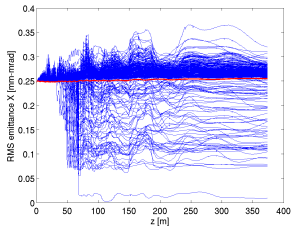


Figure: Centroid X

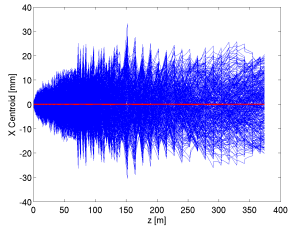


Figure: RMS Emittance Z

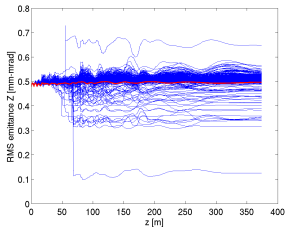
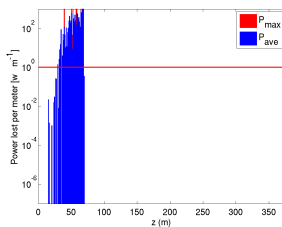


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]





# (010) Solenoids $\phi_x = 5$ mrad

Figure: RMS Emittance X

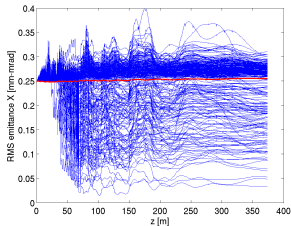


Figure: Centroid X

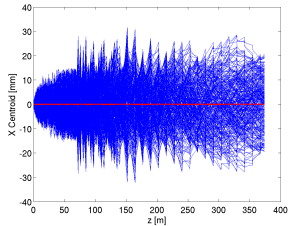


Figure: RMS Emittance Z

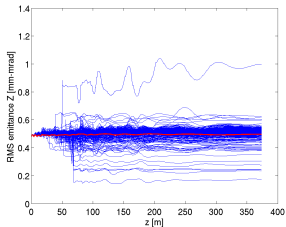
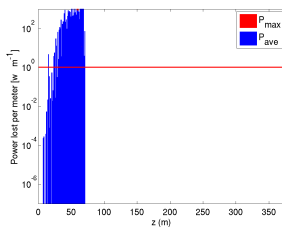


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (011) Solenoids $\delta_{xy} = 150 \mu\text{m}$

Figure: RMS Emittance X

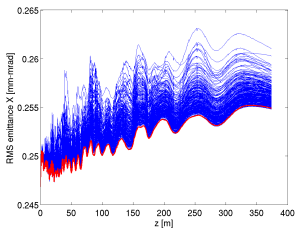


Figure: Centroid X

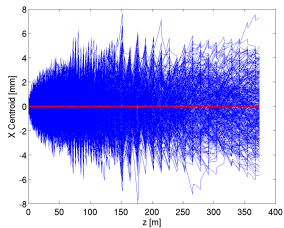


Figure: RMS Emittance Z

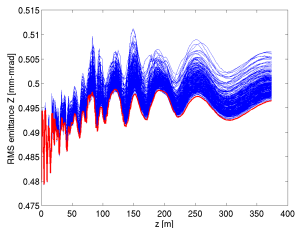
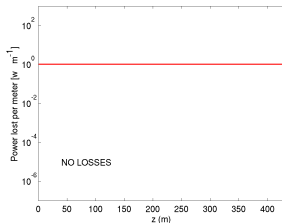


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (012) Solenoids $\delta_{xy} = 300 \mu\text{m}$

Figure: RMS Emittance X

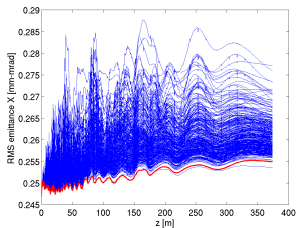


Figure: Centroid X

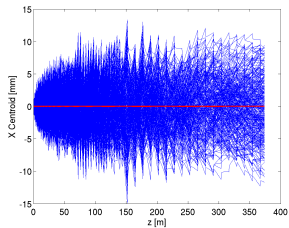


Figure: RMS Emittance Z

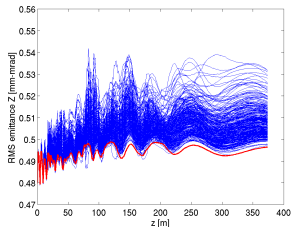
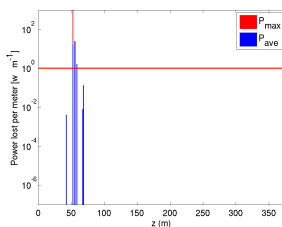


Figure: Losses  $[\text{W} \cdot \text{m}^{-1}]$



# (013) Solenoids $\delta_{xy} = 500 \mu\text{m}$

Figure: RMS Emittance X

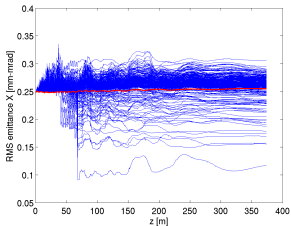


Figure: Centroid X

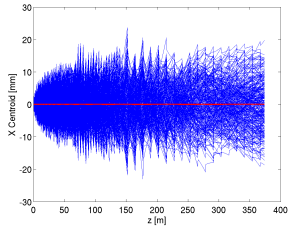


Figure: RMS Emittance Z

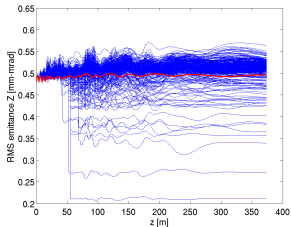
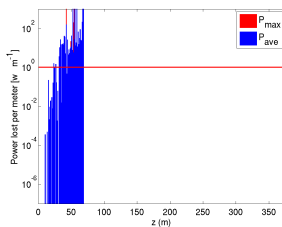


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (014) Solenoids $\delta_{xy} = 750 \mu\text{m}$

Figure: RMS Emittance X

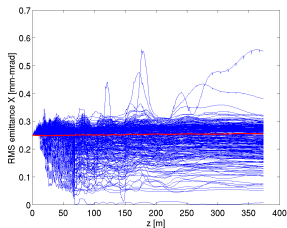


Figure: Centroid X

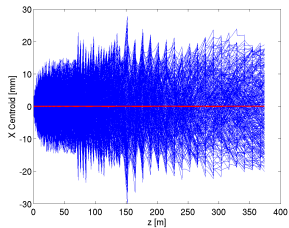


Figure: RMS Emittance Z

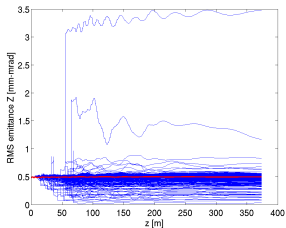
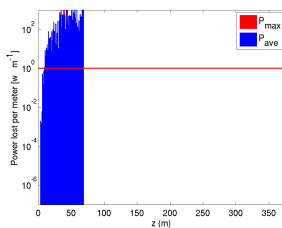


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (015) Solenoids $\delta_{xy} = 1000 \mu\text{m}$

Figure: RMS Emittance X

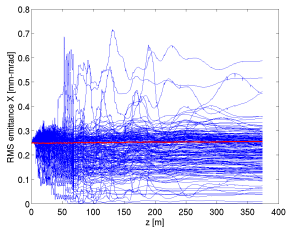


Figure: Centroid X

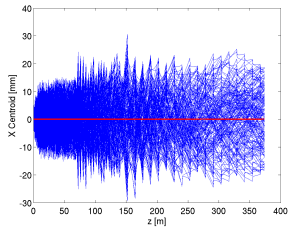


Figure: RMS Emittance Z

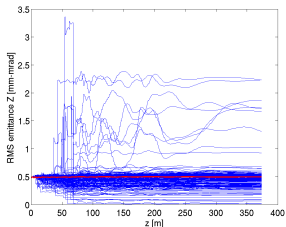
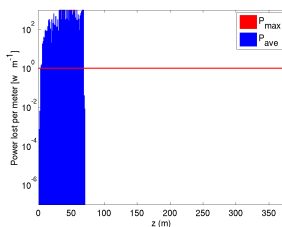


Figure: Losses  $[\text{W}\cdot\text{m}^{-1}]$



# (016) Quads $\delta_x = 150 \mu\text{m}$

Figure: RMS Emittance X

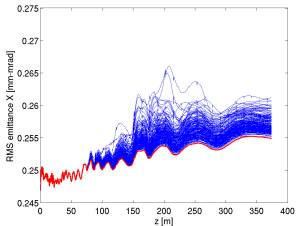


Figure: Centroid X

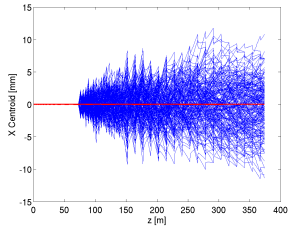


Figure: RMS Emittance Z

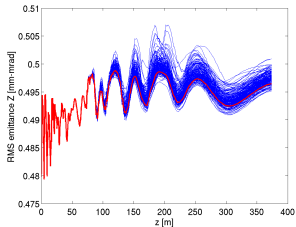
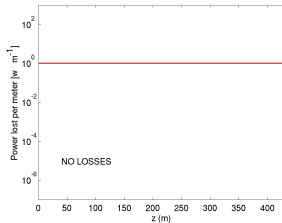


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (017) Quads $\delta_x = 300 \mu\text{m}$

Figure: RMS Emittance X

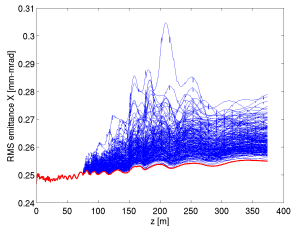


Figure: Centroid X

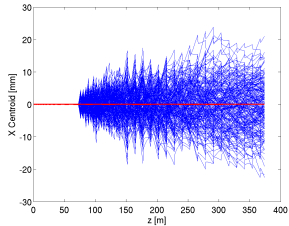


Figure: RMS Emittance z

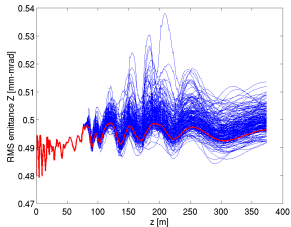
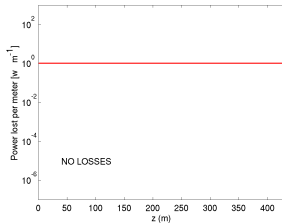


Figure: Losses  $[\text{W}\cdot\text{m}^{-1}]$





# (018) Quads $\delta_x = 500 \mu\text{m}$

Figure: RMS Emittance X

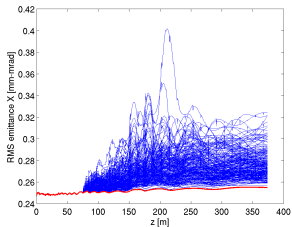


Figure: Centroid X

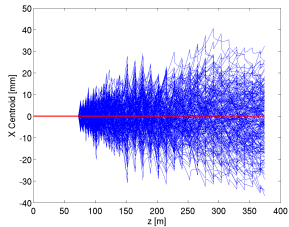


Figure: RMS Emittance Z

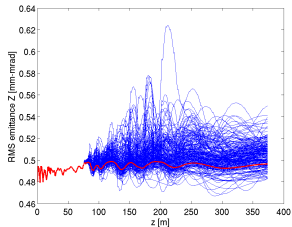
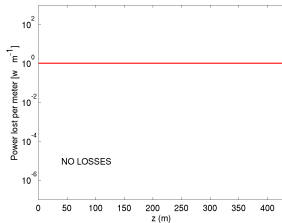


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (019) Quads $\delta_x = 750 \mu\text{m}$

Figure: RMS Emittance X

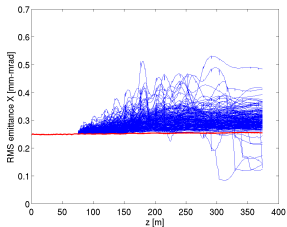


Figure: Centroid X

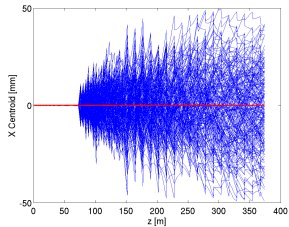


Figure: RMS Emittance Z

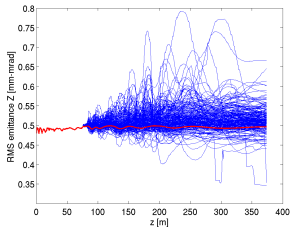
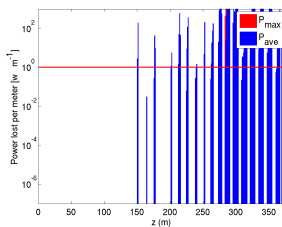


Figure: Losses  $[\text{W} \cdot \text{m}^{-1}]$



# (020) Quads $\delta_x = 1000 \mu\text{m}$

Figure: RMS Emittance X

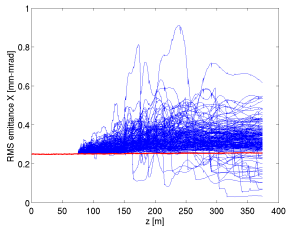


Figure: Centroid X

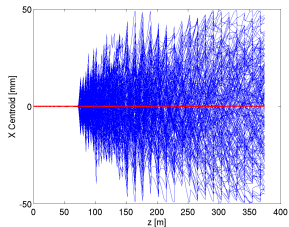


Figure: RMS Emittance Z

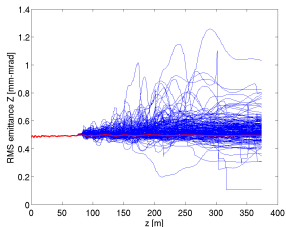
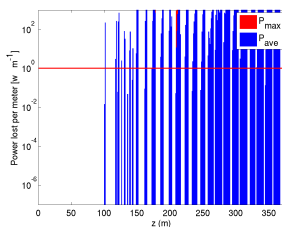


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



# (021) Quad. $\delta_{xy} = 150 \mu\text{m}$

Figure: RMS Emittance X

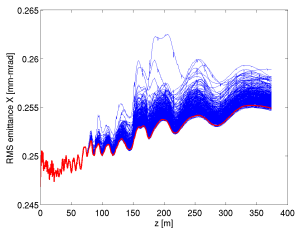


Figure: Centroid X

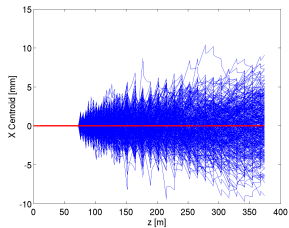


Figure: RMS Emittance Z

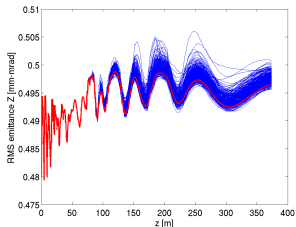
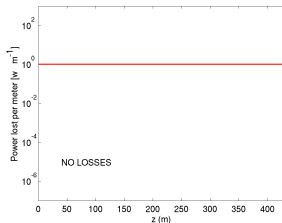


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (022) Quad. $\delta_{xy} = 300 \mu\text{m}$

Figure: RMS Emittance X

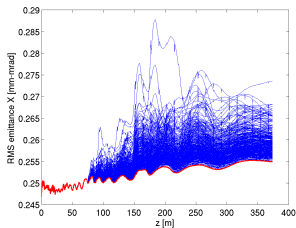


Figure: Centroid X

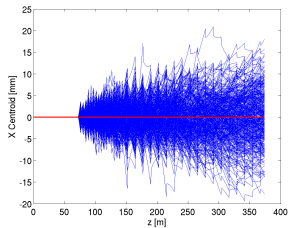


Figure: RMS Emittance Z

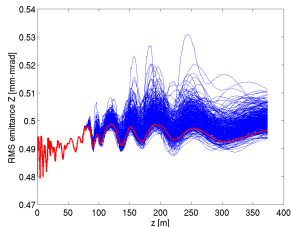
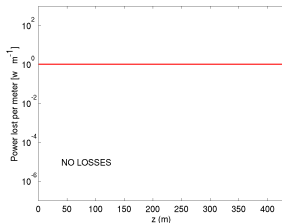


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (023) Quad. $\delta_{xy} = 500 \mu\text{m}$

Figure: RMS Emittance X

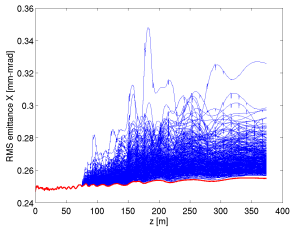


Figure: Centroid X

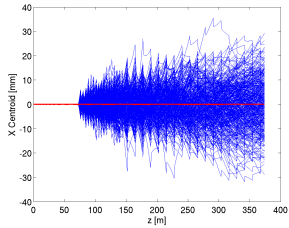


Figure: RMS Emittance Z

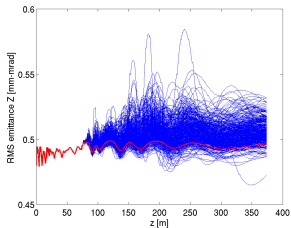
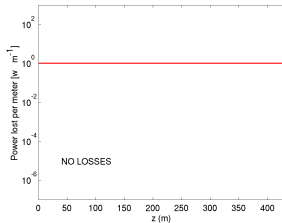


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (024) Quad. $\delta_{xy} = 750 \mu\text{m}$

Figure: RMS Emittance X

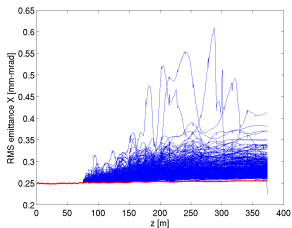


Figure: Centroid X

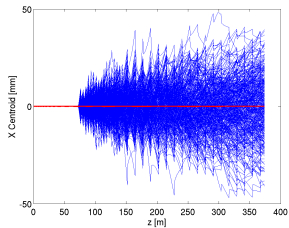


Figure: RMS Emittance Z

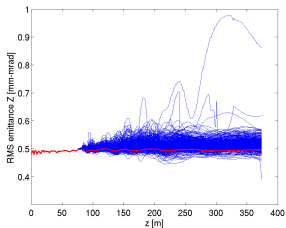
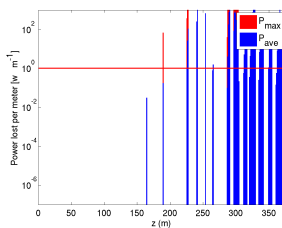


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



(025) Quad.  $\delta_{xy} = 1000 \mu\text{m}$

Figure: RMS Emittance X

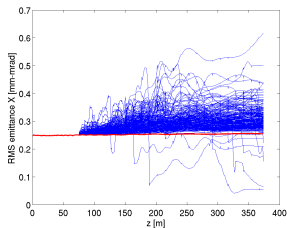


Figure: Centroid X

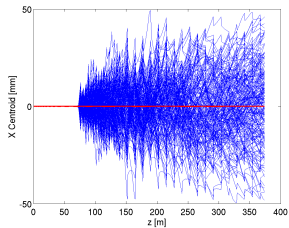


Figure: RMS Emittance Z

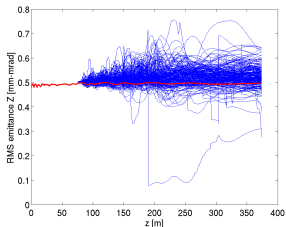
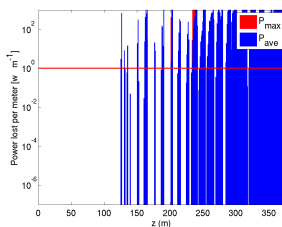


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]





# (026) Cav. Field $\delta\phi_{dyn} = 0.5^\circ$

Figure: RMS Emittance X

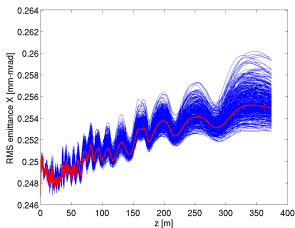


Figure: Centroid Z

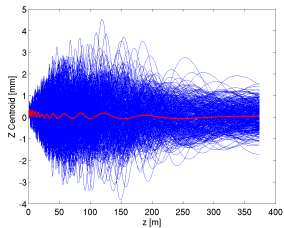


Figure: RMS Emittance Z

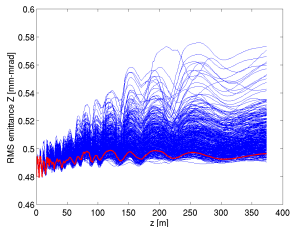
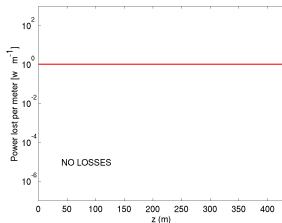


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (027) Cav. Field $\delta\phi_{dyn} = 1.0^\circ$

Figure: RMS Emittance X

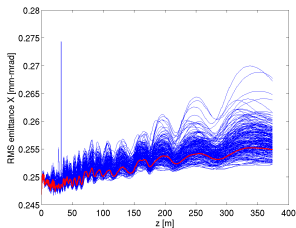


Figure: Centroid Z

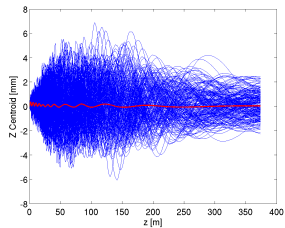


Figure: RMS Emittance z

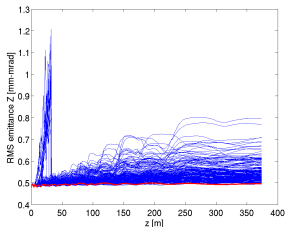
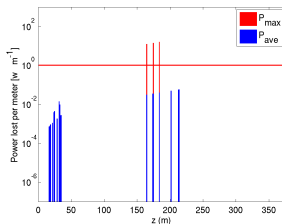


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (028) Cav. Field $\delta\phi_{dyn} = 1.5^\circ$

Figure: RMS Emittance X

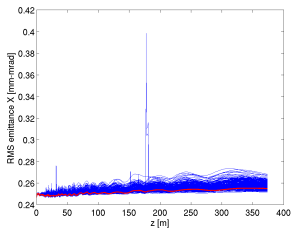


Figure: Centroid Z

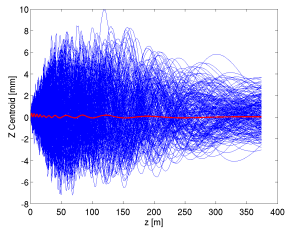


Figure: RMS Emittance Z

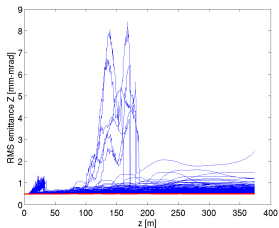
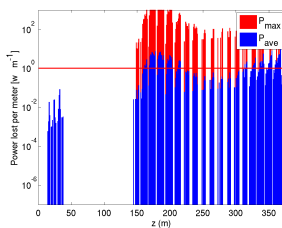


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (029) Cav. Field $\delta\phi_{dyn} = 2.0^\circ$

Figure: RMS Emittance X

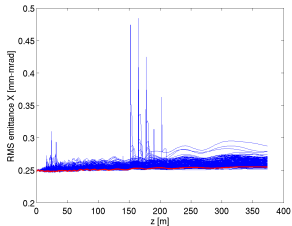


Figure: Centroid Z

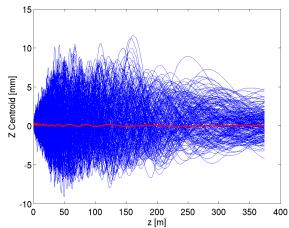


Figure: RMS Emittance Z

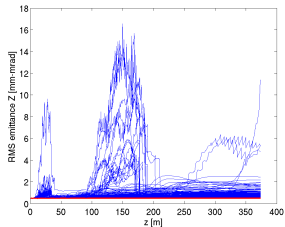
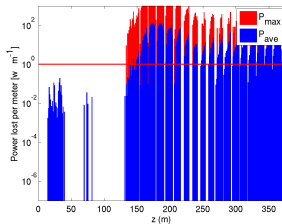


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



(030) Cav. Field  $\delta\phi_{dyn} = 2.5^\circ$

Figure: RMS Emittance X

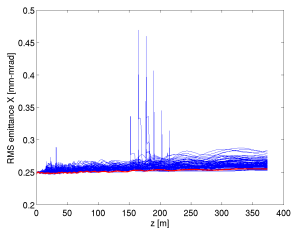


Figure: Centroid Z

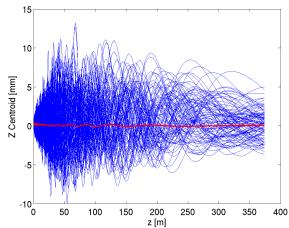


Figure: RMS Emittance Z

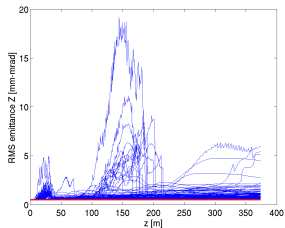
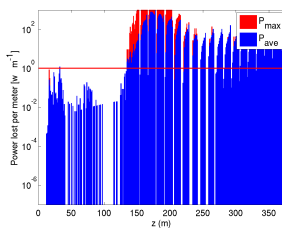


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (031) Cav. Field $\delta F_{dyn} = 0.5 \%$

Figure: RMS Emittance X

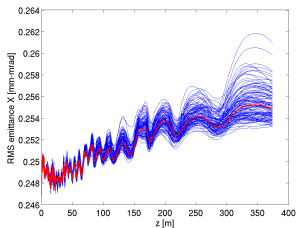


Figure: Centroid Z

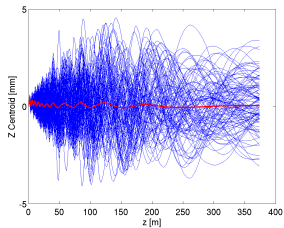


Figure: RMS Emittance Z

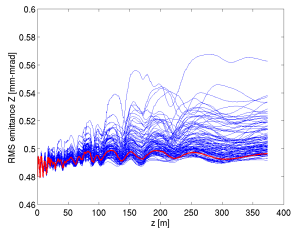
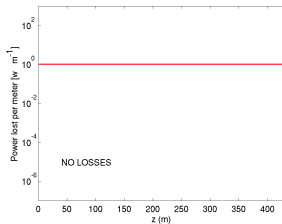


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



## (032) Cav. Field $\delta F_{dyn} = 1.0 \%$

Figure: RMS Emittance X

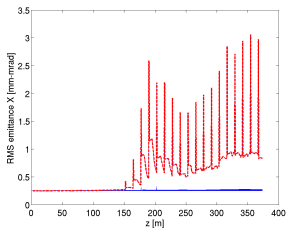


Figure: Centroid Z

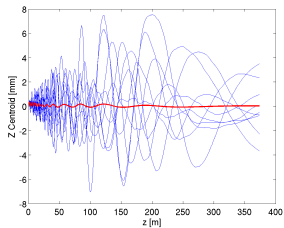


Figure: RMS Emittance Z

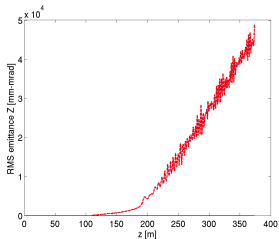
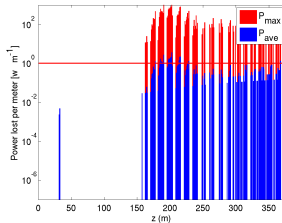


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



# (033) Cav. Field $\delta F_{dyn} = 1.5 \%$

Figure: RMS Emittance X

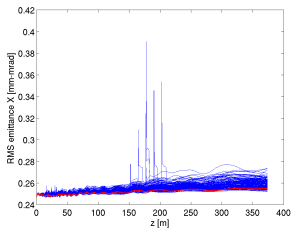


Figure: Centroid Z

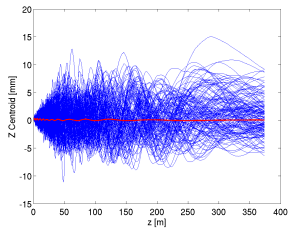


Figure: RMS Emittance Z

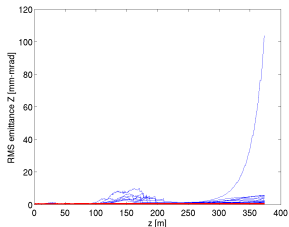
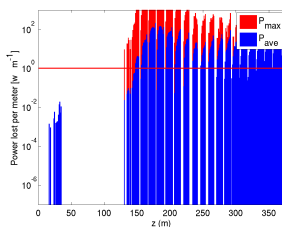


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]





# (034) Cav. Field $\delta F_{dyn} = 2.0 \%$

Figure: RMS Emittance X

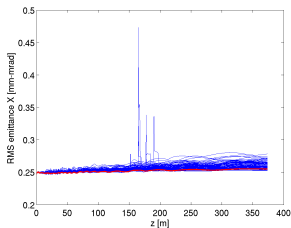


Figure: Centroid Z

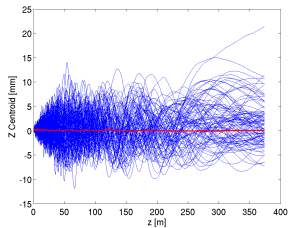


Figure: RMS Emittance Z

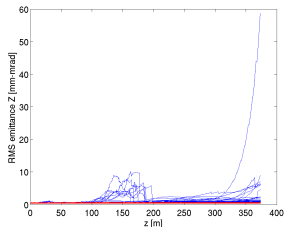
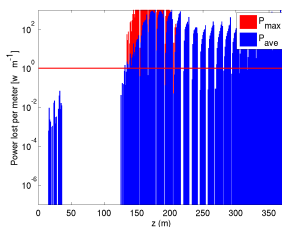


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



# (034) Cav. Field $\delta F_{dyn} = 2.5 \%$

Figure: RMS Emittance X

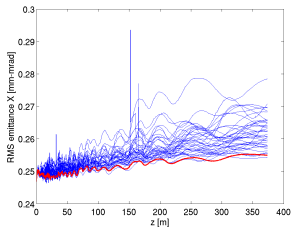


Figure: Centroid Z

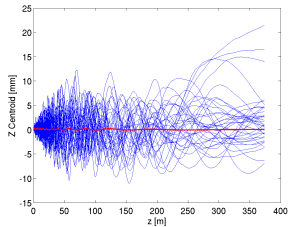


Figure: RMS Emittance Z

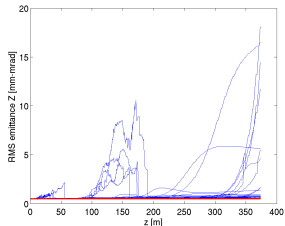
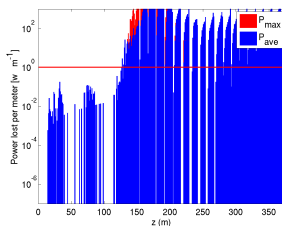


Figure: Losses [ $\text{W} \cdot \text{m}^{-1}$ ]



# (036) Cav. Phase and Field $\delta\phi_{dyn.} = 0.5^\circ$ & $\delta F_{dyn.} = 0.5\%$

Figure: RMS Emittance X

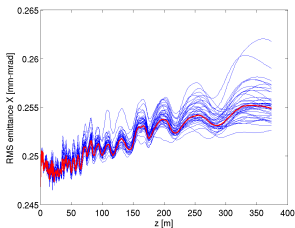


Figure: Centroid Z

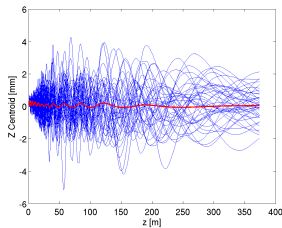


Figure: RMS Emittance Z

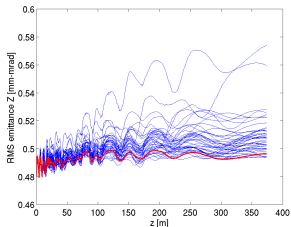
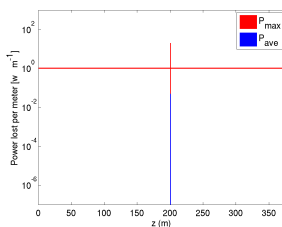


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (037) Cav. Phase and Field $\delta\phi_{dyn.} = 1.0^\circ$ & $\delta F_{dyn.} = 1.0\%$

Figure: RMS Emittance X

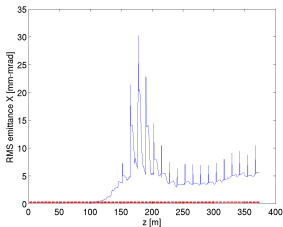


Figure: Centroid Z

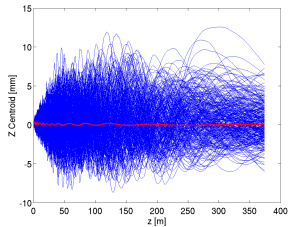


Figure: RMS Emittance Z

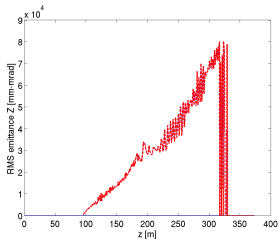
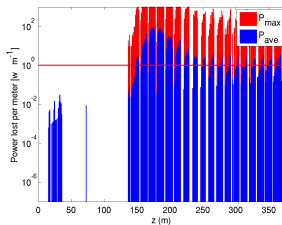


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (038) Cav. Phase and Field $\delta\phi_{dyn.} = 1.5^\circ$ & $\delta F_{dyn.} = 1.5\%$

Figure: RMS Emittance X

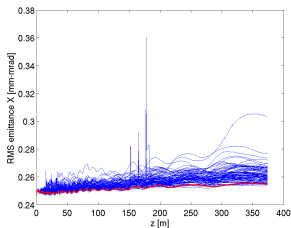


Figure: Centroid Z

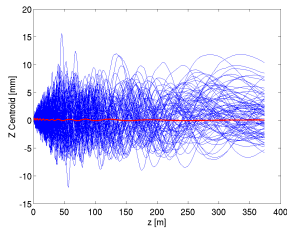


Figure: RMS Emittance Z

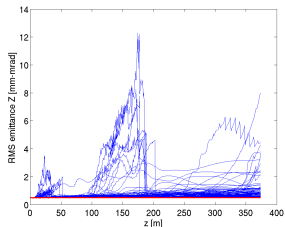
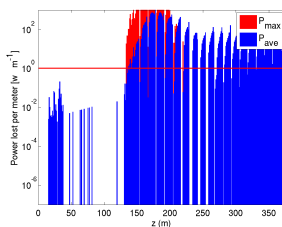


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (039) Cav. Phase and Field $\delta\phi_{dyn.} = 2.0^\circ$ & $\delta F_{dyn.} = 2.0\%$

Figure: RMS Emittance X

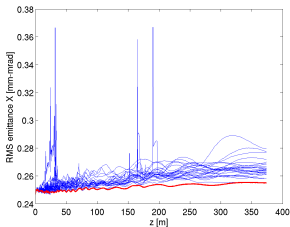


Figure: Centroid Z

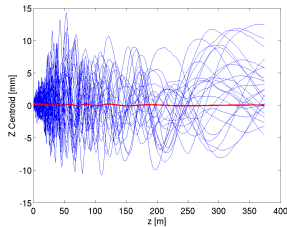


Figure: RMS Emittance Z

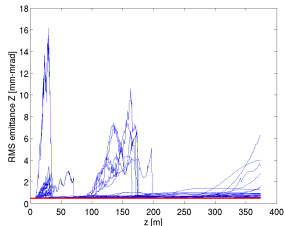
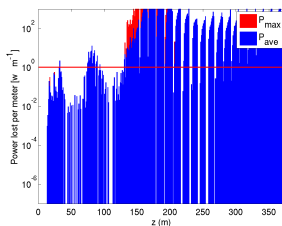


Figure: Losses [ $\text{W}\cdot\text{m}^{-1}$ ]



# (040) Cav. Phase and Field $\delta\phi_{dyn.} = 2.5^\circ$ & $\delta F_{dyn.} = 2.5\%$

Figure: RMS Emittance X

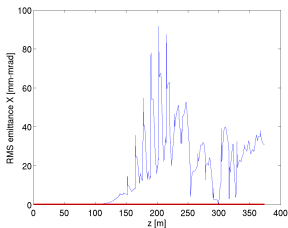


Figure: Centroid Z

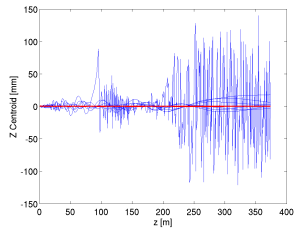


Figure: RMS Emittance Z

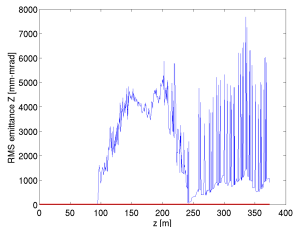


Figure: Losses  $[\text{W}\cdot\text{m}^{-1}]$

